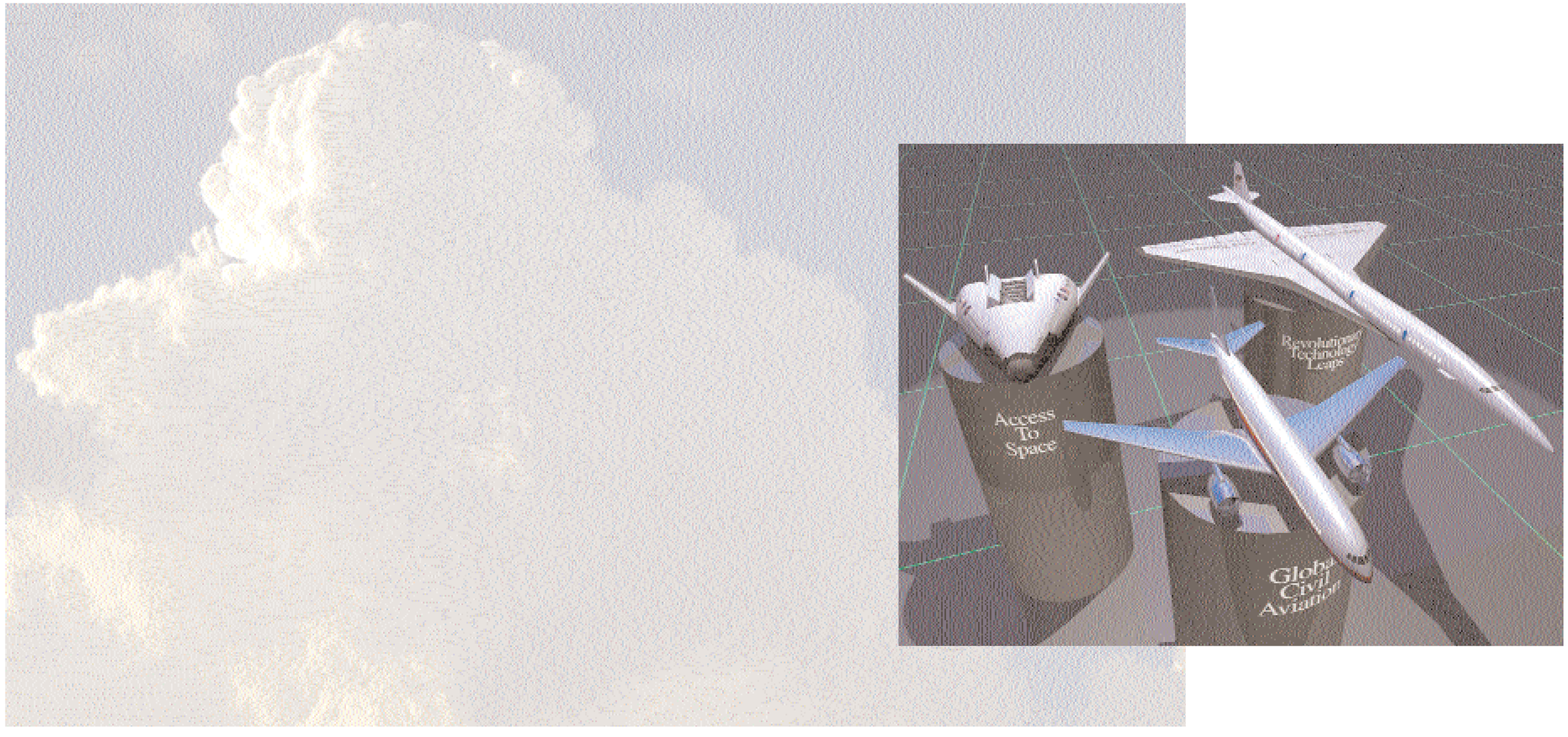
Version 1.0

Roadmaps to the Future

Strategic Roadmaps in Support of the Three Pillars and Ten Goals



Ten Enabling Technology Goals: An Introduction

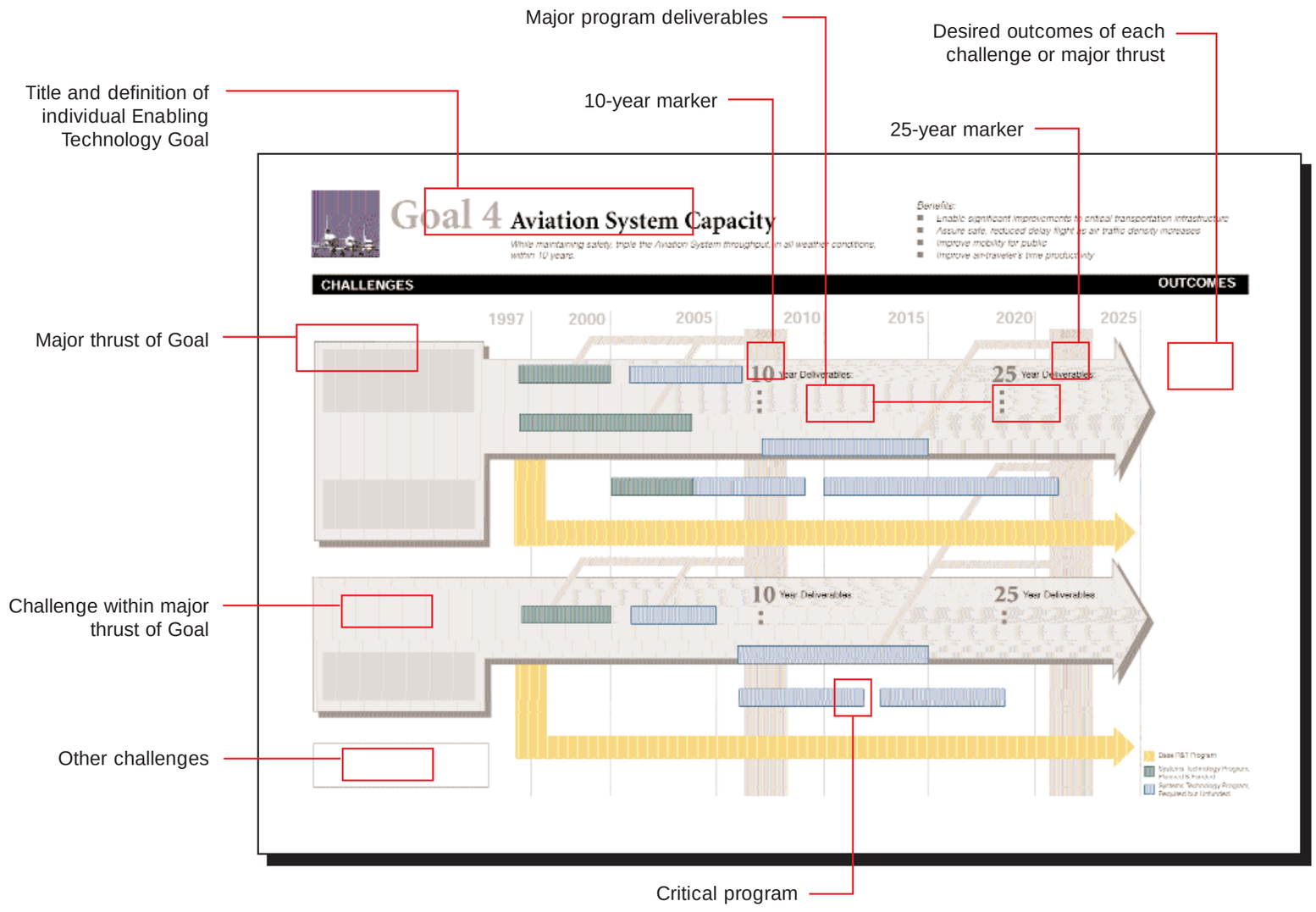
THE STRATEGIC GOALS ROADMAPS of the Aeronautics and Space Transportation Technology Enterprise are the result of significant outreach and analysis since the release of the Three Pillars for Success brochure in March 1997. The roadmaps articulate the challenges we must meet, the outcomes we seek, and the logical progression of programs that will overcome the challenges and enable the outcomes. Fundamentally, the roadmaps represent what NASA can contribute through advanced technology and new system concepts toward National goals that advance the air and space transportation interests of our Nation and the world.

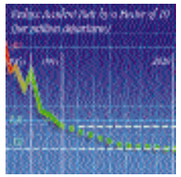
The central element of the roadmaps are the critical technology programs that are required to meet the goals. However, the goals will only be achieved through the application of the technologies to real operational systems. Therefore, it is fundamental that we perform these programs in partnership with the air and space transportation manufacturing and operational communities. It is therefore critical that we continue to build and evolve the roadmaps over time to ensure the flow of technologies into service.

The roadmaps will form the basis for the interactive strategic plan we will build on our web site. They will lead you into the heart of our technology programs. The roadmaps will evolve over time as we learn more through our research and our partnerships.

We invite your input and your involvement. It is only through partnership that we will achieve these goals and create the future of air and space transportation.

The illustration at right offers a guide on how to read each roadmap.





Goal 1 Aviation Safety

Version 1.0

Reduce the aircraft accident rate by a factor of five within 10 years, and by a factor of 10 within 25 years

Benefits:

- *Safer air transportation worldwide*
- *Dramatic reduction in aviation fatalities*
- *Eliminate safety as an inhibitor to a potential tripling of the aviation market*

CHALLENGES

System Monitoring & Modeling

Access to and exploitation of vast quantities of operational data from diverse world-wide sources

Developing analysis techniques which establish nominal baselines and detect off-nominal conditions and trends

Proprietary nature of safety and operation data which limit system-wide sharing

Accident Prevention

Identifying interventions which impact entire CFIT, Weather, and Loss of Control categories of accidents

Developing methods to dramatically reduce effect of human error by improving pilot situation awareness and decision-making

Developing affordable solutions for Commercial, General Aviation, and Rotorcraft applications

Accelerating implementation of new safety technologies for the existing fleet as well as new designs through partnerships with industry and FAA

Accident Mitigation

Lack of proven analysis methods for crashworthy designs

Difficulty in retrofitting structural modifications and long lead time for new aircraft designs

Industry concerns over liability and cost issues

OUTCOMES

1997 2000 2005 2007 2010 2015 2020 2022 2025

FAA NAS Architecture
Phase I | Phase II | Phase III

CAPACITY — Adv. Air Traffic Technologies
NAS performance monitoring

10 Year Deliverables:
- Off-line system monitoring

25 Year Deliverables:
- Technologies for real-time system monitoring

Monitor for Safety

Aviation Safety Program
Phase I System Monitoring & Modeling — Airborne performance monitoring; Accident precursor identification
Phase II — Automated hazard prediction; international data sharing; GA monitoring capability

Integration of Intelligent Aviation Systems
Real-Time Monitoring of Aviation Systems
Combine and exploit ATC, aircraft, and operational data for imbedded predictive safety information

Information Technology
Develop the fundamental concepts and technologies to enable development of Intelligent Aviation Systems

Airspace Operations Systems
Initiate development of aircraft performance measurement tools for off-line monitoring

World-wide aviation monitoring allowing continuous insight and assessment of system health and operations

AGATE Flight Systems

HSR Flight Deck

Space-Based Aviation Safety System Technologies (Code S)
Develop applications of satellite detection/measuring instruments for world-wide lightning, volcanic ash, terrain mapping, weather forecasting, and other beneficial aviation information

10 Year Deliverables:
- Reduction in key accident categories

25 Year Deliverables:
- Technologies for elimination of key accident categories

Equip for Safety

Aviation Safety Program
Phase I: System-Wide Accident Prevention; Single A/C Accident Prevention; Weather Accident Prevention
Phase II
Develop and demonstrate integrated applications of on-board, system-wide, and weather accident prevention technologies to reduce accident rates in key categories

Ultra-Safe Airborne Technology Integration
Develop next generation airborne systems for error proof operations

Elimination of recurring accident causes and early detection and prevention of new accident categories

Airspace Operations — Develop fundamental human factors methodologies and operational weather applications
Airspace Operations Systems — Advance aging aircraft and other supporting analysis and design tools, methods, and techniques
Rotorcraft — Pilot aiding and rotorcraft-unique safety technologies
Propulsion — Engine fan containment and ultra-safe design guidelines
Flight Research — Flight integration of intelligent controls design and other airborne evaluations

Safety-Configured X-Plane Design and Demonstration
Demonstrate (through simulation, full-scale impact tests, and flight evaluation) applications of flight deck, systems, and structural safety technologies in a single vehicle design

AGATE Crashworthiness

10 Year Deliverables:
- Initiate retrofit of existing fleet

25 Year Deliverables:
- Technologies for new designs incorporating systems approach to safety

Design for Safety

Aviation Safety Program
Phase I Crashworthiness; Post-Crash Fire
Phase II
Phase I: Validate impact dynamic analysis codes and develop post-crash fire mitigation technologies
Phase II: Develop crashworthiness design guidelines, and evaluate implementable post-crash fire mitigation systems

Airframe Systems — Advance aging aircraft and other supporting analysis and design tools, methods and techniques
Rotorcraft — Rotorcraft-unique crashworthy design techniques

Increased survivability of the rare accidents and incidents that do occur

PRELIMINARY

Base R&T Program

Systems Technology Program, Planned and Funded

Systems Technology Program, Required but Unfunded

Goal 2 Reduce Emissions of Future Aircraft

Version 1.0

Reduce CO_2 emissions of future aircraft by 25% within 10 years, by 50% within 25 years, and possibly totally within 30 to 40 years; and reduce NOx emissions of future aircraft by a factor of three within 10 years, by a factor of five within 25 years, and possibly totally within 30 to 40 years

Benefits:

- *Near term: Substantially mitigate aviation's contribution to climate change and degradation of local air quality and the ozone layer*
- *Far term: Significantly or totally eliminate aircraft emissions as a source of climate change and degradation of local air quality and the ozone layer*

CHALLENGES | **OUTCOMES**

1997 | 2000 | 2005 | 2010 | 2015 | 2020 | 2025

2007 | 2022

NO_X Emissions

Eliminate airport growth restrictions because of local air quality concerns even with a significant increase in aircraft operations, and reduce concerns with aviation's contribution to ozone layer recovery

AST Emissions

Demonstrate technologies capable of reducing NO_X emissions from engines by 50%

Environmental Compatibility Reduce NOx Emissions 67%

10 Year Deliverables:

Hydrocarbon Fueled Aircraft Emissions Reductions:

- 67% in NO_X

Environmental Compatibility Reduce NO_X Emissions 80%

25 Year Deliverables:

Future Aircraft Emissions Reductions:

- 80% in NO_X for H/C fueled A/C, or
- 100% in NO_X for non-H/C fueled A/C

Significantly increased safe, affordable aircraft operations with minimal NO_X emissions impact on local air quality and the ozone layer

CO_2 Emissions

Reduce aviation's contribution to climate change even with a significant increase in aircraft operations

Environmental Compatibility Reduce CO_2 for H/C Fueled A/C

- Airframe
- Propulsion
- Opts./Modeling/Integration

AST Weight & Efficiency

Demonstrate technologies capable of reducing fuel burned

AATT/FAA CNS/ATM

Demonstrate improved ATM to improved operational efficiency with reduced fuel burned

10 Year Deliverables:

Hydrocarbon Fueled Aircraft Emissions Reductions:

- 25% in CO_2

◆ Decision on improving only hydrocarbon fueled aircraft or considering also non-hydrocarbon fueled aircraft

25 Year Deliverables:

Future Aircraft Emissions Reductions:

- 50% in CO_2 for H/C fueled A/C, or
- 100% in CO_2 for non-H/C fueled A/C

Significantly increased safe, affordable aircraft operations with minimal CO_2 emissions impact on climate change

Zero CO_2 Emissions

Environmental Compatibility Eliminate or Reduce CO_2

- Airframe
- Propulsion
- Opts./Modeling/Integration

Emissions reduction technologies must not impact safety and need to be consistent and compatible with affordable air travel

Emissions reduction technologies need to be consistent and compatible with noise reduction technologies and airspace operations

Improved aircraft operations to reduce emissions must be compatible with capacity improvements

Propulsion Systems — Smart Green Engine, HiTEMP, GAP and PPM will provide technology options for more efficient hydrocarbon fueled aircraft as well as particulate/aerosol measurement capabilities if developed to the TRL 6

Airframe Systems — Morphing Technology and Futuristic Airframe Concept & Technology (FACT) will provide technology options for more efficient hydrocarbon fueled aircraft if developed to the TRL 6

DOE Infrastructure Programs (H2, CH4, etc.)
FAA CNS/ATM, DOD IHPTET

PRELIMINARY

- Base R&T Program
- Systems Technology Program, Planned and Funded
- Systems Technology Program, Required but Unfunded
- Other Agencies

Version 1.0

Goal 3 Noise Reduction

Reduce the perceived noise levels of future aircraft by 1/2 (10dB) from today's subsonic aircraft within 10 years, and by 3/4 (20dB) within 25 years

Benefits:

- *Develop technology to reduce community noise impact*
- *Objectionable aircraft noise confined within airport boundaries*
- *Potential for curfew free, unconstrained operations and growth*
- *Improved competitiveness*

CHALLENGES

OUTCOMES

1997 2000 2005 2010 2015 2020 2025

2007 2022

Global Challenges

For the public good reduce community noise impact due to subsonic air transportation while enabling natural growth of the air transportation system

Operations not constrained by noise

Objectionable aircraft noise confined within airport boundaries

Source Noise Reduction

Enable safe, efficient engine systems with 13 dB source noise reduction relative to 1997

Enable safe, efficient airframes with 12 dB source noise reduction relative to 1997

Enable more efficient airplane and engine structures, integration, and performance to achieve 3 dB community noise reduction

Eco Noise

AST Noise Reduction

Reduce community noise impact 10 dB relative to 1992 production technology

10 Year Deliverables:

- EIS 10 dB community noise impact reduction (relative to 1997)

25 Year Deliverables:

- EIS 20 dB community noise impact reduction (relative to 1997)

Reduced community noise impact due to safe, efficient airplane systems with 13dB total source noise reduction relative to 1997

More efficient, lighter weight, quiet airplane systems

Eco Emissions

Airplane system efficiency improvements

AST Propulsion Program

AST Composites & Integrated Wing Des.

- Lightweight airplane systems
- Increased airframe efficiency
- Advanced high-lift design tools

AST Noise Reduction / AGATE

- Quiet GA propellers

High Speed Research Liner and jet noise advanced technology

Airframe Systems Base Fundamental research in airframe systems noise reduction

Propulsion Base Fundamental research in propulsion systems noise reduction

AST Civil Transport & Rotorcraft Low noise concepts and operations

To include computational aeroacoustics resulting in quiet, efficient airframe/engine systems

PRELIMINARY

Operational Noise Benefits

Enable high-capacity, noise-minimal operations resulting in an equivalent community noise impact reduction of 4 dB

Terminal Area Productivity

Demonstrate technologies to enable Terminal Area operations in IMC at today's VMC rates

Extended Operations Systems

Extend the technologies to enable NAS-wide application of free-flight operations concept

Technology for Advanced Operational Concepts

Develop new technologies to enable advanced ops concept for IFR operations beyond current VFR rates

Advanced Air Traffic Technology

Demonstrate automated ATM decision aids to enable increased operations safely and efficiently

Noise sensitive air traffic management incorporating real-time controller decision aids to achieve minimal noise impact operations

Aviation Operations Systems Develop advanced operations concepts and fundamental supporting technologies to demonstrate feasibility of advanced ops concepts

FAA, DoD and Other Government Agencies

- Base R&T Program
- Systems Technology Program, Planned and Funded
- Systems Technology Program, Required but Unfunded
- Other Agencies
- Necessary Program

Goal 4 Aviation System Throughput

While maintaining safety, triple the Aviation System throughput, in all weather conditions, within 10 years.

Version 1.0

Benefits:

- *Enable significant improvements to critical transportation infrastructure*
- *Assure safe, reduced delay flight as air traffic density increases*
- *Improve mobility for public*
- *Improve air-traveler's time productivity*

CHALLENGES

OUTCOMES

1997 2000 2005 2010 2015 2020 2025

Operations Systems

Continued safe and efficient air traffic management with a significant increase in aircraft operations

Enable new operational concepts for airspace utilization

Eliminate capacity reductions due to adverse weather conditions and systems inefficiencies

Significantly increase the timeliness and utility of operational and safety information throughout the National Airspace System

FAA NAS Architecture (2007 – 2022)

Phase I | **Phase II** | **Phase III**

Terminal Area Productivity
Demonstrate technologies to enable Terminal Area operations in IMC at today's VMC rates

Extended Operations Systems
Extend the technologies to enable NAS-wide application of free-flight operations concept

Advanced Air Traffic Technology
Demonstrate automated ATM decision aids to enable increased operations safely and efficiently

10 Year Deliverables:
- "Free Flight" operations concept (with FAA)
- IMC operations at current VMC rates
- 1st generation decision support tools & automation aids

25 Year Deliverables:
- New operations paradigm
- All ops beyond today's VMC rules
- 2nd generation ATM/AOS tools
  - integrated strategic/tactical planning
  - autonomous monitoring & advisories

Technology for Advanced Operational Concepts
Develop new technologies to enable advanced ops concept for IFR operations beyond current VFR rates

Aviation Safety Program

Phase I
Develop airborne performance modeling and accident precursor identification

Phase II
Enable automated hazard prediction, international data sharing, and GA monitoring capability

Integration of Intelligent Aviation Systems
Enable distributed, intelligent, automated safety-critical monitoring/advisories to increase safety and improve operational efficiency

Information Technology Develop the fundamental concepts and technologies to enable development of Intelligent Aviation Systems

Aviation Operations Systems Develop advanced operations concepts and fundamental supporting technologies to demonstrate feasibility of advanced ops concepts

Safe, efficient air traffic management with all-weather operation beyond current clear-weather capacity

Real-time, distributed intelligent automated aviation system-wide monitoring with safety and operational advisories

Aircraft Configuration

Increase system capacity and capability without significant airport expansion

Significantly improve aircraft / airport productivity

Eliminate operational limitations due to environmental restrictions
(see Noise & Emissions Roadmaps)

Expand the efficient, effective utilization of the Nation's 5400 public-use airports for air transportation
(see General Aviation Roadmap)

Short-Haul Civil Tilt Rotor
Demonstrate technologies for complex low-noise flight paths and acquire full-span data-base for low-noise rotors

Short-Haul Civil Tilt Rotor 2
Demonstrate technologies for simultaneous non-interference ops and neighborhood-friendly rotorcraft

10 Year Deliverables:
- Simultaneous, non-interference, neighborhood-friendly rotorcraft operations

25 Year Deliverables:
- High capacity, unobtrusive operations of runway independent vehicles
- Technologies for high-productivity, weather-tolerant vehicles
- Demonstrated intermodal operations

Advanced Runway Independent Vehicle Systems
Demonstrate technologies for high capacity, unobtrusive operations of runway independent air vehicles

Revolutionary High Productivity Vehicle Systems
Enable very high productivity intermodal vehicle systems

Intermodal Operations Demo
Feasibility demonstration of system operation of intermodal and rotorcraft aircraft

Rotorcraft Develop the fundamental concepts and technologies to enable development of advanced cost-effective runway-independent aircraft

Airframe Systems, Propulsion Systems Advanced concepts and technologies to support high productivity and intermodal operations

Expanded, high productivity utilization of short-runway and runway independent aircraft within an expanded NAS

High productivity, weather-tolerant vehicle systems with intermodal operations capability

PRELIMINARY

- Base R&T Program
- Systems Technology Program, Planned and Funded
- Systems Technology Program, Required but Unfunded
- Other Agencies

Goal 5 Affordable Air Travel

Reduce the cost of air travel by 25 percent within 10 years, and by 50 percent within 25 years.

Version 1.0

Benefits:

Radically improve mobility for the traveling public, making the commercial air transportation system:

- *More affordable through reduced ticket prices*
- *More accessible through seamless passenger and cargo intermodal transportation to significantly increase system productivity*
- *More available through 24 hour operations*

CHALLENGES

OUTCOMES

1997 2000 2005 2010 2015 2020 2025

Reduction in Acquisition and Operating Cost

Need for revolutionary configurations to meet aggressive reduced-cost/seat metrics

Solve barrier issues to enable introduction of breakthrough aircraft technologies that significantly reduce acquisition and operational costs

AST Reduced Seat Cost

Will deliver revolutionary low-cost and light weight composite wing methodology and airframe & turbomachinery analysis tools that will enable advanced airframe and engine designs

Revolutionary Aircraft Efficiency Program

Provide large scale validation of barrier technology challenges in aerodynamic efficiency, structures, sub-systems, and propulsion systems that inhibit development of new generations of advanced aircraft configs capable of dramatic acquisition and operating cost reductions

2007

10 Year Deliverables:

- Technologies to reduce the cost of air travel by 25%, nominal 7¢ per ASM
- Validated low-cost, lightweight non-traditional airframes
- Efficient aero performance analysis tools for revolutionary configurations
- Validated simple, fault tolerant engine systems
- Light weight, low-cost subsystems
- Advanced IT tools for multi-disciplinary optimization

2022

Introduction of new configurations utilizing advanced technologies with acquisition and operating cost metrics unachievable through evolutionary improvement

Airframe Systems Advanced concept systems studies of rev. efficient configs, preliminary analysis of non-traditional airframe components, and demonstrate integrated high fidelity methods for non-linear problems

Propulsion Assessment of cost-effective highly loaded turbo machinery concepts

Operations and System Productivity Improvement

Significant increases in aircraft productivity

Development of new aircraft / airport operational paradigms

AST Noise Reduction

Provides 10dB noise reduction to enable 24-hour operations

Revolutionary High Productivity Vehicle Systems

Highly Reliable Subsystems Program

Develop distributed power and self-healing vehicle health management systems required for intermodal aircraft

Revolutionary High Productivity Vehicle Systems

Modular Smart Airframe Program

Solve barrier technology challenges to provide durable, real-time health monitored ultra low-noise intermodal airframes

Revolutionary High Productivity Vehicle Systems

Design Environment Integration Program

Provide aircraft/airport optimization system required for increased load factors and system utilization with introduction of intermodal and rotorcraft aircraft

25 Year Deliverables:

- Technologies to reduce the cost of air travel by 50%
- Technologies to increase aircraft productivity by 30%
  - Durable, real-time health-monitored ultra low-noise intermodal airframes
  - Distributed power and self-healing vehicle health management systems
  - Weather-tolerant operations
  - Aircraft/airport optimization system required for increased load factors and system utilization

Intermodal Aircraft / Airport Seamless Ops Demo

Feasibility demonstration of system operation with intermodal and rotorcraft aircraft

Introduction of aircraft technologies to significantly improve the flexibility and productivity of intramodal operations and enable intermodal transportation, significantly increasing passenger and cargo system productivity and availability

Eliminate operational limitations due to environmental restrictions
(see Noise & Emissions Roadmaps)

Significantly increase the efficiency and productivity of the National Airspace System
(see Aviation System Throughput Roadmap)

Airframe Systems Base Advanced concept systems benefit studies of intermodal transports and breakthrough embedded airframe technologies for active control to enable efficient, low noise concepts

Propulsion Reduced fuel burn turbo machinery concepts

Rotorcraft Assessment of low-cost R/C component technologies

PRELIMINARY

Base R&T Program

Systems Technology Program, Planned and Funded

Systems Technology Program, Required but Unfunded

Goal 6 High Speed Travel

Reduce travel time to the Far East and Europe by 50% within 25 years, and do so at today's subsonic ticket prices

Version 1.0

Benefits:

- *Provides increased passenger travel-time productivity*
- *Provides improved airline efficiency and asset deployment*
- *Protects US world leadership for long-haul transporters*
- *Potential for 140,000 new jobs and $409B swing of trade balance*

CHALLENGES **OUTCOMES**

1997 2000 2005 2010 2015 2020 2025

HSCT Enabling Technology Maturation

Minimize the environmental impact of emissions

Comply with noise standards for vehicle class

Achieve vehicle economics competitive with subsonics

Airframe/Prop./Flight Deck Technology Dev. (HSR II)

Propulsion/Airframe Component Development/Demonstration (HSR IIA)

High Speed Research (HSR) Programs II and IIA: Develop and demonstrate economically viable critical component and system level technologies and environmental solutions to support industry's HSCT launch decision

Industry Internal Research and Development

Provide critical proprietary and under-funded technologies to support HSCT product launch

Integrated High Performance Turbine Engine Technology (IHPTET)

Provide key technologies for an efficient, environmentally compatible propulsion system

2007

10 Year Deliverables:

Technology for an HSCT, i.e.:
- Mach 2.4
- Environmentally Compliant
- Competitive Surcharge

Integrated Full-Scale Technology Demonstrations (NASA/Industry)

Provide validated performance of full-scale propulsion and air-frame component technologies for an HSCT

HSR Technology Insertion Programs (DoD, Industry)

Provide higher maturity, lower cost technologies in support of an HSCT product launch

HSCT Pre-Launch Development (Industry)

Provide integrated technologies for all systems and sub-systems of an HSCT

2022

25 Year Deliverables:

Technology for an HSCT, i.e.:
- Mach 2.4
- Environmentally Compliant
- No Surcharge

HSCT Launch (Industry)

Engineering and manufacturing development of the economically viable, compliant, US-led HSCT

Atmospheric Effects of Stratospheric Aircraft (Atmospheric Effects of Aviation)

Assess the potential environmental impact of an HSCT fleet and provide expert advice for Industry and Government relating to certification and implementation

Mature and available technologies that enable an economically viable, environmentally compliant U.S. HSCT

PRELIMINARY

- Base R&T Program
- Systems Technology Program, Planned and Funded
- Systems Technology Program, Required but Unfunded
- Other Agencies

Revolutionary Concepts for High Speed Systems

Dramatically improve high speed vehicle economics

All Provide fundamental technologies in support of economic and environmental improvements for an HSCT

Supersonic Overland Demonstrate low sonic boom breakthrough technologies for supersonic aircraft

Pulse Detonation Technologies Provide fundamental knowledge related to feasibility of pulse detonation propulsion for economical high speed flight

Demonstration of high-risk high-payoff technologies for revolutionary approaches to low-cost supersonic travel

HSCT Operations Systems

Achieve seamless intelligent aviation system integration

All / REVCON Provide breakthrough technologies for high speed travel

Capacity (TAP, AATT, etc.)

Provide the Intelligent Aviation System infrastructure-related technologies to achieve HSCT "free flight"

Aviation Operations Systems / Information Technology Develop the concepts enabling advanced operations within an Intelligent Aviation System

Free-flight operations for an HSCT fleet

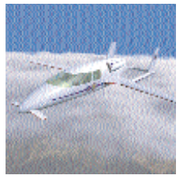
Low-Cost Design / Manufacturing

Keep vehicle economics competitive with subsonics

Aviation Industry Programs for Cost Reduction

Provide dramatic time and cost savings in developing and manufacturing new/production aircraft

Dramatically reduced costs for designing and manufacturing new/production aircraft



Goal 7 General Aviation

Invigorate the general aviation industry, delivering 10,000 aircraft annually within 10 years, and 20,000 aircraft annually within 25 years.

Version 1.0

Benefits:

- *Every suburban, rural and remote community or county shall be served within a 30 mile radius by a Small Air Transportation System (SATS)-compliant airport with SATS compliant aircraft*
- *Safe, affordable and convenient direct access to over 5000 U.S. destinations at 4 times the average speed of highway travel*

CHALLENGES

OUTCOMES

1997 2000 2005 2010 2015 2020 2025

2007 2022

Vehicle Technologies

Significantly reduce acquisition and life cycle costs

Eliminate operational limitations due to environmental restrictions

Significantly increase safety, ease of use and reduce training time

AGATE

- COTS-based avionics hardware and software systems
- Streamlined composite materials qualification and certification
- Unified instrument-private pilot training curriculum

GAP

Affordable, quiet compression-ignition and small turbine engines

10 Year Deliverables:

- Ultra-efficient, low cost airframe, propulsion and avionics technologies
- Situational awareness and crashworthiness technologies
- Advanced, easy-to-use, “Highway in the Sky” graphical displays

25 Year Deliverables:

- Technologies for low-cost software development / certification
- Synthetic / enhanced vision with simplified controls and training
- Quiet, non-hydrocarbon propulsion technologies

SATS Vehicle Technologies R&T

Capstone I: Integrated Systems Advanced Conc. Project

Capstone II: Alternative Configurations Advanced Conc. Project

- Human factors
- Automation in lower-cost structures and materials
- Advanced flight controls
- Advanced propulsion concepts and components

Airframe Systems, Propulsion Systems, Flight Research

Vehicles that approach automobiles in their affordability and ease-of-use while dramatically improving general aviation safety

Quiet, clean propulsion for non-curfewed 24 hour per day operations

Infrastructure Technologies

Significantly increase the number of GA accessible, all-weather destinations (Class C, D, E & G airspace)

AGATE Heli-STAR

AGATE Datalink Facility

- Free Flight equipage and procedures
- Advanced communication / navigation surveillance (CNS)
- “Highway in the Sky” datalink systems

10 Year Deliverables:

- Validation of component technologies required for wide access to general aviation airports in adverse weather conditions (ADS-B; WAAS/LAAS DGPS; Flight, Traffic, and Commercial Information Datalink)

25 Year Deliverables:

- Validation of total system concept
  - “Smart” public-use / general aviation airports connected through Free Flight / Satellite-based CNS architecture

SATS I: USIP Intra-State Transportation System Development Projects

SATS II: Advanced USIP InterState System Concept Integration & Demonstration

- Verification of infrastructure technology requirements as basis for Federal, State and Local public policy supporting public investments
- Satellite-based CNS
- Information technologies for infrastructure
- Air Traffic Management (ATM) in non-radar, non-towered airspace

Aviation Operations Systems, Information Technology

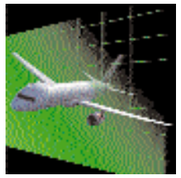
Ability to safely and efficiently utilize in near-all-weather conditions the nation’s 5400 public use airports as an integral element of an inter-modal personal transportation system

PRELIMINARY

Base R&T Program

Systems Technology Program, Planned and Funded

Systems Technology Program, Required but Unfunded



Goal 8 Design Tools and Experimental Aircraft

Provide next-generation design tools and experimental aircraft to increase design confidence, and cut the development cycle time for aircraft in half *(Note: Roadmap refers to Next Generation Design Tools only)*

Benefits:

- *Rapid insertion of new technologies, including public benefit items such as safety, emissions, etc.*
- *Improved early and effective evaluation of revolutionary concepts*
- *Containment of NASA program design and development costs*
- *Early identification of design-based issues and avoidance of errors*
- *Improved cost management through early availability of knowledge*

CHALLENGES

OUTCOMES

1997 2000 2005 2007 2010 2015 2020 2022 2025

Integration

Provide seamless integration of modules, infrastructure, and architecture to include all design practices, processes and disciplines and all phases of the product life-cycle

10 Year Deliverables:
- High-fidelity physics-based analyses

25 Year Deliverables:
- Full life-cycle simulations & optimizations

R&D Testbed and Advanced Concept Demonstrations

Demonstrate practical operation of the full suite of next-generation design tools

Life-Cycle Integration

Integrate disciplinary analyses and synthesize life-cycle phases and processes into an intelligent design-cycle system

Seamless, integrated parallel design processes; Analysis-based certification; Full life-cycle modeling and optimization; Seamless, fully-integrated tools

Architecture

An architecture that is flexible, provides seamless integration of design tools with intelligent design aids, captures expertise, and provides fast access to expanded archives

HPCC

Enable parallelization and high-speed computing

10 Year Deliverables:
- Object-level tool interfaces

25 Year Deliverables:
- Design tools for seamless design processes

Information Management Systems

Develop advanced tools for information management and exploitation, as well as interfaces for seamless environments

Adaptive Multidisciplinary Environment

Develop technology that provides innovative, knowledge-based analyses, allows easy access to the new, information-based design environment, and integrates tools into single distributed, collaborative environment

Intelligent design aids; Process management advisory; Automated design guidance; Worldwide distributed collaboration; Direct access to relevant knowledge; Object-level tool interfaces

HPCC & Information Technologies

Develop high-capacity network infrastructure as well as advanced capabilities for data mining and intelligent agents operating reliably across a wide variety of platforms and protocols

Infrastructure

Develop an infrastructure providing fast, secure, high-capacity communication, improved sensing and measurement, rapid and flexible testing and full-process visualization

HPCC

Develop high-capacity network infrastructure as well as advanced capabilities for data mining and intelligent agents operating reliably across a wide variety of platforms and protocols

10 Year Deliverables:
- High-speed / capacity computing and networking
- Intelligent measurement systems
- Capabilities for rapid, accurate test / validation

25 Year Deliverables:
- Full sensory, immersive collaboration technologies
- Intelligent aids and agents
- Radical instrumentation methods and test / validation capabilities

High-Speed Communications

Provide the capability to operate reliably across a wide variety of platforms and protocols

Telepresence with full sensory immersive environments; Low-cost, high accuracy, quick-turnaround, non-intrusive measurement; Validated full-scale test data; Rapid, secure, intelligent, seamlessly-integrated design-to-test environment

Rapid, Accurate Test Technologies

Provide lightweight, highly accurate, non-intrusive measurement systems for both hard-ware and software, and innovative techniques and systems for faster, more efficient data acquisition and analysis and rapid validation of new designs and design tools; Develop test and analysis techniques to provide validated full-scale test article data

Intelligent Design, Analysis and Test Systems

Develop a validated seamless design-through-test environment, and rapid capabilities for developing test articles

Modules

Develop streamlined design processes that provide rapid, variable-fidelity simulation and synthesis of physics and model all processes

HSR, AST

Develop portions of improved physics-based methods for single-discipline analysis

10 Year Deliverables:
- High-fidelity models / methods
- Quantified confidence levels

25 Year Deliverables:
- Knowledge-based analysis / synthesis methods
- Intelligent processes
- Analysis-based certification capability

High Fidelity Concurrent Design Methods

Provide tools for “out-of-the-box” thinking and reliable cost analysis and management, and develop enhanced physics-based methods for multidisciplinary analyses

Nearly instantaneous computations for rapid, full physics-based, variable fidelity, fully time-scaled analyses; All processes are modeled; Minimal / no component testing needed

AFS, AOS, Prop., Rotorcraft & Flight Research

Models for Life-Cycle Simulation

Enable vastly-accelerated component, process and system analyses and real-time communication and simulations by using non-traditional and radical computer technologies

Note: Roadmap is synergistic with NASA's ISE / IS initiatives

- Base R&T Program
- Systems Technology Program, Planned and Funded
- Systems Technology Program, Required but Unfunded

Goal 9 Low-Cost Space Access

Reduce the payload cost to low-Earth orbit by an order of magnitude, from $10,000 to $1,000 per pound, within 10 years, and by an additional order of magnitude, from thousands to hundreds of dollars per pound, within 25 years

Version 1.0

Benefits:

- *Enable a "Highway to Space" which will create a new space marketplace*
- *Increased U.S. space launch market share*
- *Enable commercial investment in and operation of space systems*

CHALLENGES

OUTCOMES

1997 2000 2005 2010 2015 2020 2025

2007 2022

Medium/Heavy

Drive down operations cost

Drive down manufacturing and productions costs

Drive down development costs

Increase system performance

X-33

RLV Risk Reduction or New Orbit Demonstrator

Technical Risk Reduction

Integrated Orbital Sys. Demonstrator

X-34

10 Year Deliverables:

- $1,000 per pound

25 Year Deliverables:

- $100's per pound

Technology Flight Demos and Experiments

Flight Experiments

Multi Purpose Flight Demo

High Op Tempo Flight Demo

Advanced Technology Flight

Phase III RLV Integrated Flight Demo(s)

2nd Generation Airframe and Propulsion

3rd Generation Airframe and Propulsion

Phase I: Small Scale

Phase II: Large Scale

Phase III: 3rd Generation

Highly reliable, fully reusable transportation to earth orbit for Medium / Heavy class payload

Trailblazer X Planes

Pathfinder X Planes

Focused Technology

High Performance, Highly Operable Propulsion Systems, Structures, TPS and Subsystems
Aeronautics

Small Scientific

Drive down operations cost

Drive down manufacturing and productions costs

Drive down development costs

Increase system performance

Integrated Flight Demo #1

Integrated Flight Demo #2

Technology Flight Demo(s)

10 Year Deliverables

- $3,000 per pound

Launch Assist Tech Flight Demo

Air Augmented Engine Demo

Beamed Energy

Advanced Airframe and Propulsion Systems

Selected Long Term Phase III Technologies

Phase III Enhancing Technologies

Virtual Concepts Development

Phase I: Unique Enabling Technologies

Highly operable, reusable, reliable transportation to earth orbit for ultra-lite and small class scientific payloads

High Performance, Highly Operable Propulsion Systems, Structures, TPS and Subsystems (Phase II)
Space Transportation Research
Aeronautics

PRELIMINARY

Base R&T Program

Systems Technology Program, Planned and Funded

Systems Technology Program, Required but Unfunded

Goal 10 In-Space Transportation

Version 1.0

Reduce the cost of interorbital transfer by an order of magnitude within 15 years, and reduce travel time for planetary missions by a factor of two within 15 years, and by and order of magnitude within 25 years

Benefits:

- *Enable a "Highway to Space" which will create a new space marketplace*
- *Increased U.S. space launch market share*
- *Enable commercial investment in and operation of space systems*

CHALLENGES

OUTCOMES

1997 2000 2005 2010 2015 2020 2025

2007 2012 2022

Earth Orbital

Long life, high power electric propulsion

Advanced, clean chemical engines

Reusable systems

Chem/Electric Technology Demo

Technology Flight Experiments and Demo(s)

Solar Thermal Flight Experiment

Tether Flight Experiment

Clean Propellants (Shuttle Upgrades)

High Power Electric Thrusters

Aerocapture & Cryo Fluid Management Technologies

Advanced Chemical Stages

Reusable Upper Stage Demo

- Chemical
- Chemical / Aerocapture
- Solar Electric
- Solar Thermal
- Tethers

10 Year Deliverables:
- 2x cost reduction

15 Year Deliverables:
- 10x cost reduction

Enable highly reliable, fully reusable space transfer operations

Eliminate toxic chemical propellants

Trailblazer X Planes

Pathfinder X Planes

Focused Technology

Long-life, Highly Efficient Propulsion Systems / Lightweight Structures and TPS / Automated GN&C

Planetary Exploration

Ultra light systems

Precision landing systems

Aerocapture systems

Breakthrough propulsion technologies to enable at least two orders of magnitude increase in specific impulse

NSTAR (DS-1)

Next Generation Ion Demo

Early Interstellar Technology Demo

25 Year Deliverables:
- 10-100x Time Reduction

Enable ambitious planetary exploration program(s) within $ caps

Ultra-Lightweight Propulsion Components

Chemical Propulsion Components

Electric Propulsion Components

Next Generation Oriented

Solar/Laser Sails, Magnetic Sails, Ultra High-Power Plasma Thrusters

Develop viable propulsion options for Interstellar missions

Space Transportation Research Interstellar Mission Oriented: Fusion, Matter / Anti-Matter, Solar Laser Sails

PRELIMINARY

Base R&T Program

Systems Technology Program, Planned and Funded

Systems Technology Program, Required but Unfunded